

**Effect of Row Spacing and Nitrogen levels on
growth, yield and quality of Nigella
(*Nigella sativa* L.)**

THESIS



submitted to the

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In

HORTICULTURE

PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS

by

RAHUL KUMAR GOUTAM

Department of Plantation, Spices, Medicinal and Aromatic Crops

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior

College of Horticulture, Mandsaur (M.P.) - 458001

2016

CERTIFICATE - I

This is to certify that the thesis entitled “**Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)**.” submitted in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE in Horticulture Plantation, Spices, Medicinal and Aromatic Crops**, of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (Madhya Pradesh) is a record of the bona-fide research work carried out by **Mr. Rahul Kumar Goutam**, ID. NO. 144L05, under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of these investigations has been acknowledged by the scholar.

(Dr. Inder Singh Naruka)

Chairman of the Advisory Committee

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Chairman (Dr. I. S. Naruka)

Co-Chairman (Dr. S. S. Kushwah)

Member (Dr. R. P. S. Shaktawat)

Member (Dr. G. P. S. Rathore)

CERTIFICATE – II

This is to certify that the thesis entitled “Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)” submitted by Mr. Rahul Kumar Goutam, ID. NO. 144L05, to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN HORTICULTURE** in the department of **Plantation, Spices, Medicinal and Aromatic Crops** has been accepted after evaluation by the External Examiner and approved by the Student’s Advisory Committee after an oral examination on the same.

Place: Mandsaur

Date: 10/11/2016

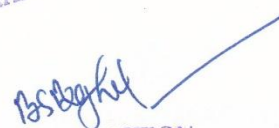


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Member (Dr. R. P. S. Shaktawat) :
Member (Dr. G. P. S. Rathore) :
Head of the Department/Head of the Section:
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Director Instructions:



DIRECTOR INSTRUCTION
R.V.S.K.V.V., GWALIOR (M.P.)

Dean
College of Horticulture
MANDSAUR (M. P.)

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ABBREVIATIONS USE IN TEXT

/	:	Per
@	:	At the rate of
%	:	Percentage
ANOVA	:	Analysis of variance
B : C	:	Benefit Cost ratio
C.D.	:	Critical difference
cm	:	Centimeter
°C	:	Degree Celsius
Cv.	:	Cultivar
D.F.	:	Degrees of freedom
DAS	:	Days after sowing
<i>et al.</i>	:	and others
Fig.	:	Figure
g	:	Gramme
ha.	:	Hectare
hr	:	Hour
i.e.	:	That is
R.V.S.K.V.V.	:	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
K	:	Potassium
Kg	:	Kilogram
Kg ha ⁻¹	:	Kilogram per hectare
Max.	:	Maximum
Min.	:	Minimum
MOP	:	Murate of potash
M.S.S.	:	Mean sum square
N	:	Nitrogen
No.	:	Number
NS	:	Non significant
P ₂ O ₅	:	Phosphorus
R.H.	:	Relative humidity
Rs.	:	Rupees
R	:	Coefficient of correlation
SEm	:	Standard error of mean
Sig.	:	Significant
q ha ⁻¹	:	Quintal per hectare
Viz.	:	(Videlicet) Namely

Chapter-I

INTRODUCTION

Nigella (*Nigella sativa* L.) is a minor and annual herbaceous seed spice crop belonging to the family Ranunculaceae. *Nigella* is commonly called as 'kalonji'. It is native to the mediterranean region through west asia to north India. It is widely cultivated throughout South Europe, Syria, Egypt, Saudi Arabia, Iran, Pakistan, India and Turkey. In India, it is commercially cultivated in Punjab, Himachal Pradesh, Madhya Pradesh, Jharkhand, Assam, West Bengal and Andhra Pradesh. In India *nigella* seeds are used as preservative in all sorts of homemade pickles. *Nigella* seed is used for seasoning of vegetables, legumes and different type of baked products. The oil of *nigella* seed has also demand in the pharmaceutical and perfumery industry. The main alkaloids present in *nigella* seeds are nigellmin, nigellidin, nigellicine and possess anticarcinogenic properties (Rana *et al.* 2012).

The genus *Nigella* contains about 20 species of annual herbs, the most popular of which is *Nigella sativa* L. The name *Nigella* derives from the Latin *nigellus* or *niger*, meaning black. It is commonly called as black cumin and is popular by different names in different countries. It is called as black cumin or small fennel in English. The *Nigella* plant is an erect, herbaceous annual plant, with height ranging from 30 to 60 cm. (Malhotra and Peter 2004).

The seed contain about 21% protein, 35% carbohydrates and 35-38% oil; 1.5% (volatile) and 37.5% (Non-volatile). Seed is rich source of albumen, sugar, organic acids, and glucoside melanthin metarbin (Adil *et al.* 2014).

Nigella is a cool season crop, requiring a frost free growing season and is cultivated in the northern plains, central and peninsular region of India during the winter season. Fairly warm weather during sowing with a temperature of 20–25°C is desirable. Cold weather is congenial for the early growth period and the crop requires warm sunny weather during seed formation.

Chapter-I

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harvesting solar energy, phosphorylated compounds in energy transformations, nucleic acids in the transfer of genetic information and the regulation of cellular metabolism and of protein as structural units and biological catalysts is well known (Rana *et al.* 2012).

Row spacing and nitrogen levels play very important role in securing higher yield of a crop in particular set of agro climate condition. Therefore, the present study was undertaken to study the "Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)" with the following objectives:

1. To find out the effect of row spacing on growth, yield and quality of nigella.
2. To find out the effect of nitrogen levels on growth, yield and quality of nigella.
3. To find out the suitable combination of row spacing and nitrogen levels for optimum growth and productivity of nigella.

Chapter-II

REVIEW OF LITERATURE

The literature pertaining to the “**Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)**” is presenting in this chapter. Similar work on other crops has also been reviewed to understand the effect of different treatments under experimentation.

Effect of row spacing

Chaudhary (1999) studied the response of cumin to row spacing. Row spacing of 15, 22.5 and 30 cm recorded significantly higher mean seed yields (2.69-2.85 q ha⁻¹) over broadcast sown crop (2.45 q ha⁻¹) produced significantly higher mean seed yield (3.01 and 3.00 q ha⁻¹). Row spacing of 22.5 cm gave the maximum mean seed yield of 3.55 q ha⁻¹.

Amin *et al.* (2005) reported that crop sown on 45 cm row spacing recorded significantly higher seed and stover yields and its attributes of fennel. Whereas, growth attributes increased with increase in row spacing from 30 to 60 cm.

Bahraminezhad and Papzan (2006) revealed that when the seeds of nigella were planted in 40 cm row spacing, the grain yield was highest (660 Kg ha⁻¹) and was significantly different when compared with means of the other treatments. The average oil and essence percentages of seeds in this study were 28% and 0.148%, respectively.

Pawar *et al.* (2007) conducted a field experiment to study the influence of graded levels of spacing and nitrogen on growth and yield of coriander. Result revealed maximum leaf yield per hectare in 30 x 10 cm spacing.

Malhotra and Vashishtha (2008) studied the response of nigella (*Nigella sativa* L.) variety NRCSS AN-1 to different agro-techniques under semi-arid conditions. Results reveals that the essential oil content increased significantly when crop was sown at wider spacing of 40 cm.

Meena *et al.* (2011) reported that crop geometry of 25 × 10 cm gave the highest plant height at 40 and 90 DAS as well as at harvest, number of capsule plant⁻¹, number of seeds capsule⁻¹ and test weight. Sowing of nigella on 15th October at 25 × 10 cm row to row and plant to plant spacing, respectively was best for higher growth and yield of nigella.

Mehta *et al.* (2011) studied the effect of growth, profitability and productivity of fennel as influenced by crop geometry (40 cm x 25 cm, 50 cm x 25 cm and 60 cm x 25 cm). Results reveals that crop geometry of 60 cm x 25 cm resulted in significantly higher seed yield. Thus, 60 cm x 25 cm was optimum for realizing higher yield, profitability and productivity of fennel.

Meena *et al.* (2012) reported that crop geometry of 25 × 10 cm significantly resulted in the highest plant height at all stage of growth. Similarly, number of capsule per plant, number of seeds per capsule, 1000 seed weight, seed yield and essential oil content in nigella were also maximum with crop geometry of 25 cm × 10 cm.

Naruka *et al.* (2012) conducted field experiment to study the effect of spacing and nitrogen on the productivity and quality of ajowain. Results reveals that wider 45 x 30 cm spacing significantly increased the number of primary and secondary branches per plant at harvest, fresh weight per plant (g), dry weight per plant, days to 50% flowering, number of umbels per plant, number of umbellets per umbel, yield per plant (g) chlorophyll content of leaves (mg g⁻¹), carotenoids content of leaves (mg g⁻¹) and essential oil of seed (ml 100 g⁻¹) expect plant height (cm), seed yield (q ha⁻¹), straw yield (q ha⁻¹) and biological yield (q ha⁻¹), these attributes are maximum in 45 x 10 cm spacing. Whereas non significant effect was observed on test weight (g) and harvest index (%).

Mehta *et al.* (2013) revealed that 30 x 10 cm crop geometry is better for realizing higher seed yields higher net return and profitability in coriander production.

Meena *et al.* (2015) revealed that three crop geometry viz., 40 cm x 10 cm, 50 cm x 10 cm and 60 cm x 10 cm spacing. Results reveals that significantly higher plant height at all the growth stages, yield attributes, and seed yield (908.57 kg ha⁻¹) were obtained with sowing of dill at 40 cm x 10 cm spacing over wider spacing.

Singh and Amin (2015) revealed that fennel crop sown at 45 cm row spacing reported significantly higher seed yield (1521 kg ha⁻¹) over 30 and 60 cm row spacing. Similarly, stover yield (2270 kg ha⁻¹) and oil yield (21.92 kg ha⁻¹) was significantly superior over 30 and 60 cm row spacing.

Muvel *et al.* (2015) resulted that ajwain crop sown on 45 x 30 cm spacing significantly increased the plant height (cm), fresh weight per plant (g), dry weight per plant (g), number of umbels per plant, number of umbellets per umbel, 1000 seed weight (g), yield per plant (g), seed yield (q ha⁻¹), straw yield (q ha⁻¹) biological yield (q ha⁻¹), chlorophyll content of leaves (SPAD), carotenoids content of leaves (mg g⁻¹) and essential oil content in seed (%).

Effect of nitrogen levels

Nataraja *et al.* (2003) revealed that application of nitrogen at 100 kg ha⁻¹ recorded the maximum values for plant spread (427.75 cm²) and number of seeds (57.52) per pod. Significant differences were also observed with the interaction of NPK at 50:40:30 kg ha⁻¹ producing pods of good size (3.84 cm²), higher test weight of 1000 seeds (2.38 g) and seed yield (17.45 q ha⁻¹).

Pawar *et al.* (2007) reported that as regards nitrogen application there was increase in leaf yield per hectare in coriander with increase in levels of nitrogen. The maximum leaf yield per hectare was observed under 100 kg nitrogen ha⁻¹.

Shah and Samiullah (2007) reported that basal dose of 80 kg N ha⁻¹ affected the growth and yield parameters favourably with the exception of HI. A level of 100 kg nitrogen ha⁻¹ proved supra-optimal in nigella crop.

Shah (2007) revealed that all the treatments significantly influenced capsule number, seed yield, seed protein content, seed oil and protein yield plant⁻¹. The response to nitrogen was linear, being maximum with 80 kg N ha⁻¹.

Shah (2008) revealed that the N fed plants of nigella showed a significant enhancement of capsule number, seed yield plant⁻¹, protein and oil yield plant⁻¹, especially upon application of 352 mg N pot⁻¹.

Malhotra and Vashishtha (2008) conducted a field experiment to study the response of nigella (*Nigella sativa* L.) variety NRCSS AN-1 to different agro-techniques under semi-arid conditions reported that increased essential oil content application of nitrogen fertilizer 50 kg ha⁻¹.

Goswami (2011) revealed that irrigation at interval of 18-20 days with application of 80 kg N ha⁻¹ was found productive and economic in the sandy loam soil of Indo-gangetic plains.

Rana *et al.* (2012) revealed that application of 60 kg ha⁻¹ N and 120 kg ha⁻¹ P fertilizer with the variety AN-1 gives the maximum growth, yield and quality of nigella with highest net return per hectare.

Mehta *et al.* (2013) revealed that application of 50 kg N ha⁻¹ is better for realizing higher yields, higher net return and profitability in coriander

Patel *et al.* (2013) reported that among the levels of nitrogen @ 80 kg ha⁻¹ produce highest seed yield (1203 kg ha⁻¹) and straw yield (1596 kg ha⁻¹) and also significant improvement in growth and yields parameters viz., plant height, number of branches plant⁻¹, number of umbels plant⁻¹, number of umbellate umbel⁻¹, number of seeds umbellate⁻¹, Test weight (g) and seed weight plant⁻¹ (g). Similarly application of nitrogen @ 80 kg ha⁻¹ recorded highest quality parameters (protein content, volatile oil content and total oil yield).

Adil *et al.* (2014) revealed that grains per plant or capsule weight fluctuated by the nitrogen application. N-level 90 kg ha⁻¹ gave higher yield of nigella crop.

Siyyedani *et al.* (2014) experimented that four levels of nitrogen fertilizer (0, 33, 66 and 100 kg ha⁻¹). Results showed that 66 kg N ha⁻¹ gave the highest yield with mean of 395.1 g m⁻².

Ali *et al.* (2015) conducted a field experiment with four levels of nitrogen (0, 20, 40 and 60 kg ha⁻¹) results reveals that the maximum days to germination, plant height, number of days to first umbel maturity and seed yield kg ha⁻¹ were observed in coriander plants provided at 60 kg ha⁻¹ nitrogen.

Yimam *et al.* (2015) conducted field experiment on nigella with five levels of nitrogen (0, 15, 30, 45 and 60 kg ha⁻¹ in the form of urea). Results indicated that highest seed yield (1336.7 kg ha⁻¹), highest number of pods per plant (45.9), highest number of branches (46.1), highest number of seeds per pod (91.6), highest harvest index (20.8%), longest day to 50% flowering (86.7 days) was obtained from 60 kg N ha⁻¹.

Singh and Amin (2015) studied that the response of drilled rabi fennel under varying levels of nitrogen. Results reveals that effect of nitrogen levels from 60 to 120 kg ha⁻¹ was significant on seed and stover yield, but increase in yield from 90 to 120 kg nitrogen ha⁻¹ was at par.

Meena *et al.* (2015) conducted their experiment to study the response of varying nitrogen levels on growth and yield of Anise. Recorded maximum plant height, fresh weight per plant, dry weight per plant, number of primary branches per plant, secondary branches per plant, number of leaves per plant, number of nodes per plant, number of umbels per plant, number of umbellates per umbel, number of seeds per umbel and umbellate, test weight (g), harvest index (%), seed yield, straw yield, biological yield (q ha^{-1}) with 45 kg N ha^{-1} followed by 35 kg N ha^{-1} as compared to control.

Chapter-III

MATERIALS AND METHODS

A field experiment was conducted on “**Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)**” at the “Horticulture Experimental Farm” College of Horticulture, Mandsaur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) from October, 2015 to March, 2016. The details of the materials used and methods followed during the course of investigation are presented in this Chapter.

3.1 Experimental site

The field experiment was carried out at the “Horticulture Experimental Farm” College of Horticulture Mandsaur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior during 2015-16. The College of Horticulture, Mandsaur is situated in Malwa plateau in Western part of Madhya Pradesh at 23.45⁰ to 24.13⁰ North latitude, 74.44⁰ to 75.18⁰ East longitudes and at an altitude of 435 m above mean sea level. This region falls under Agro Climatic Zone No.10 of the State.

3.2 Climatic conditions of the experimental site

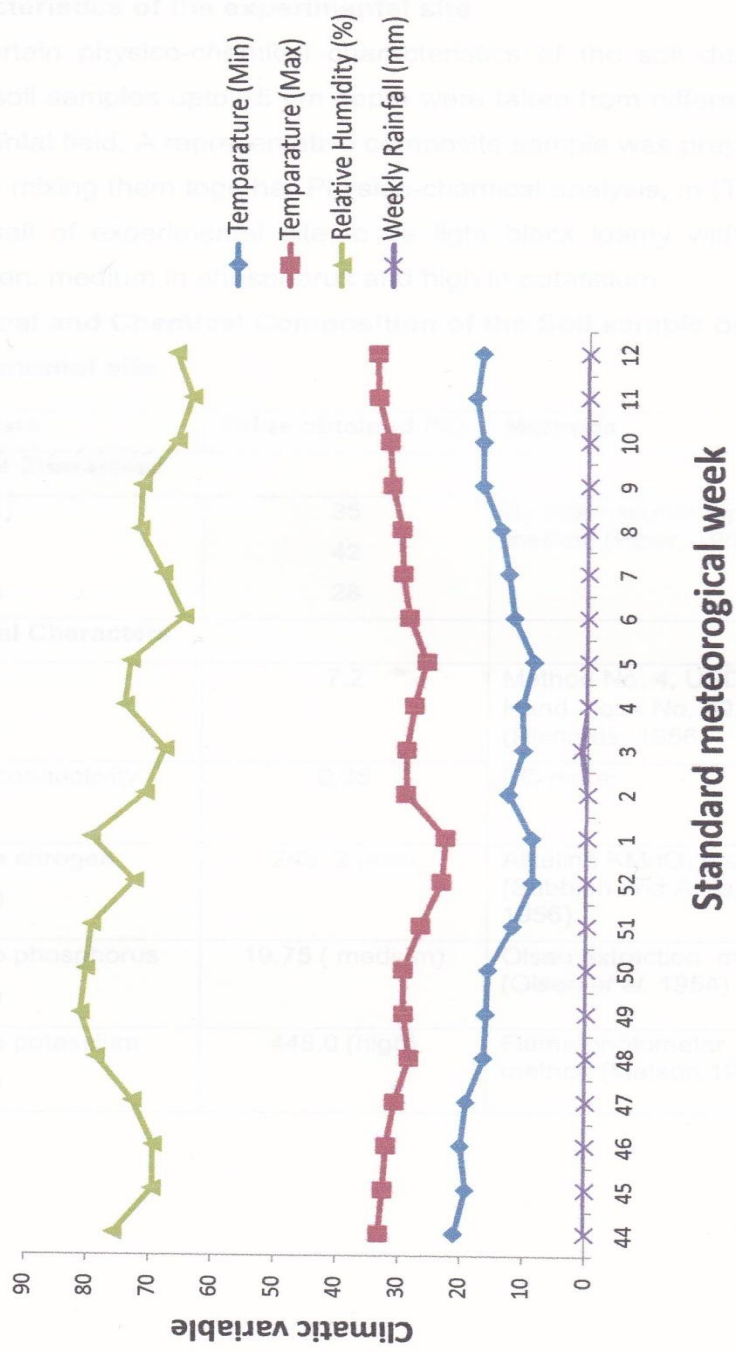
Mandsaur belongs to sub-tropical and semi-arid climatic conditions having a mean maximum temperature of 44⁰ C and mean minimum temperature of 5⁰ C in summer and winter respectively. It receives an annual average rainfall of 744.05 mm during mid June to September. South-West monsoon is responsible for major part of annual precipitation. Meteorological data recorded during the period of investigation are presented in (Table 1) and are graphically shown in (Fig 1).

Table-1 Weekly meteorological observations during the study period (Oct,- 2015 to March-2016)

Week No.	Duration	Temperature		Relative Humidity (%)	Weekly Rainfall (mm)
		Min. (°C)	Max. (°C)		
44	22 Oct to 28	21.0	33.1	75.7	-
45	29 Oct to 04	19.2	32.5	69.5	-
46	05 Nov to 11	20.0	32.0	69.4	-
47	12 Nov to 18	19.2	30.7	72.7	-
48	19 Nov to 25	16.4	28.4	78.7	-
49	26 Nov to 02	16.1	29.4	81.2	-
50	03 Dec to 09	15.8	29.5	80.4	-
51	10 Dec to 16	11.9	26.7	79.5	-
52	17 Dec to 23	8.8	23.4	72.7	-
1	24 Dec to 30	8.9	22.8	79.7	-
2	31 Dec to 06	12.7	29.2	71.1	-
3	07 Jan to 13	10.4	29.1	68.0	1
4	14 Jan to 20	10.6	27.9	74.4	-
5	21 Jan to 27	8.7	26.0	73.5	-
6	28 Jan to 03	11.9	28.8	65.0	-
7	04 Feb to 10	12.8	29.9	68.4	-
8	11 Feb to 17	14.1	30.1	72.1	-
9	18 Feb to 24	17.0	31.7	71.8	-
10	25 Feb to 02	17.0	32.1	66.2	-
11	03 Mar to 09	18.1	33.9	63.8	-
12	10 Mar to 16	17.1	34.1	66.4	-

Source: Metrological Observatory, Mandsaur (M.P.)

**Fig. 1- Climatic variables for the period of investigation
(Oct to March 2015-16)**



3.3 Soil characteristics of the experimental site

To ascertain physico-chemical characteristics of the soil during the year of study, soil samples upto 15 cm depth were taken from different spots of the experimental field. A representative composite sample was prepared by processing and mixing them together Physico-chemical analysis, in (Table 2), indicated the soil of experimental site to be light black loamy with low in available nitrogen, medium in phosphorus and high in potassium.

Table -2 Physical and Chemical Composition of the Soil sample of experimental site

S.No.	Particulars	Value obtained (%)	Methods
Physical Characters			
(a)	Sand (%)	35	By international Pipette method (Piper, 1950)
(b)	Silt (%)	42	
(c)	Clay (%)	28	
Chemical Characters			
(a)	Soil Ph	7.2	Method No. 4, USDA Hand book No. 60, (Richards, 1956)
(b)	Electric conductivity (dSm ⁻¹)	0.35	EC meter
(c)	Available nitrogen (kg ha ⁻¹)	243. 2 (low)	Alkaline KMnO ₄ method (Subbiah and Asija, 1956)
(d)	Available phosphorus (kg ha ⁻¹)	19.75 (medium)	Olsen extraction method (Olsen <i>et al.</i> 1954)
(e)	Available potassium (kg ha ⁻¹)	448.0 (high)	Flame photometer method (Metson,1956)

3.4 Experimental Details

Location	: Bahadari Farm, College of Horticulture, : Mandsaur (M.P.)
Name of crop	: Nigella (<i>Nigella sativa</i> L.)
Variety	: NRCSS AN-1
Season	: Rabi
Experimental Design	: Split Plot Design
Treatments	: 09
Replications	: 04
Total Number of plots	: 36
Total experimental area	: 289.2 m ²
Net plot size	: 5.4 m ²
Date of sowing	: 26 October 2015
Date of harvesting	: 14 March 2016

	Symbol
15 cm Row Spacing + 20 kg Nitrogen ha ⁻¹	S.N ₁
15 cm Row Spacing + 40 kg Nitrogen ha ⁻¹	S.N ₂
15 cm Row Spacing + 60 kg Nitrogen ha ⁻¹	S.N ₃
22.2 cm Row spacing + 20 kg Nitrogen ha ⁻¹	S.N ₄
22.2 cm Row spacing + 40 kg Nitrogen ha ⁻¹	S.N ₅
22.2 cm Row spacing + 60 kg Nitrogen ha ⁻¹	S.N ₆
30 cm Row Spacing + 20 kg Nitrogen ha ⁻¹	S.N ₇
30 cm Row Spacing + 40 kg Nitrogen ha ⁻¹	S.N ₈
30 cm Row Spacing + 60 kg Nitrogen ha ⁻¹	S.N ₉

3.5 Experimental details

The experimental material comprised row spacing in combination with nitrogen levels.

Factor I – Main plot treatment : Row spacing

- 15 cm (S₁)
- 22.5 cm (S₂)
- 30 cm (S₃)

Factor II – Sub plot treatment : Nitrogen levels

- 20 kg ha⁻¹ (N₁)
- 40 kg ha⁻¹ (N₂)
- 60 kg ha⁻¹ (N₃)

Table -3 The Treatment combinations were as follows

Detail of treatment	Symbol
15 cm Row Spacing + 20 kg Nitrogen ha ⁻¹	S ₁ N ₁
15 cm Row Spacing + 40 kg Nitrogen ha ⁻¹	S ₁ N ₂
15 cm Row Spacing + 60 kg Nitrogen ha ⁻¹	S ₁ N ₃
22.5 cm Row spacing + 20 kg Nitrogen ha ⁻¹	S ₂ N ₁
22.5 cm Row spacing + 40 kg Nitrogen ha ⁻¹	S ₂ N ₂
22.5 cm Row spacing + 60 kg Nitrogen ha ⁻¹	S ₂ N ₃
30 cm Row Spacing + 20 kg Nitrogen ha ⁻¹	S ₃ N ₁
30 cm Row Spacing + 40 kg Nitrogen ha ⁻¹	S ₃ N ₂
30 cm Row Spacing + 60 kg Nitrogen ha ⁻¹	S ₃ N ₃

3.5.1 Experimental layout

The experiment was laid out in a split plot design with spacing in the main plot and nitrogen levels in sub plot, having 4 replications. The treatments were randomly allotted to different plots using Random Number Table of Fisher and Yates (1963). The layout plan of experiment with allocation of treatment and other details of the experiment is shown in Fig 2



Fig. 3.5.1 Layout of the field experiment

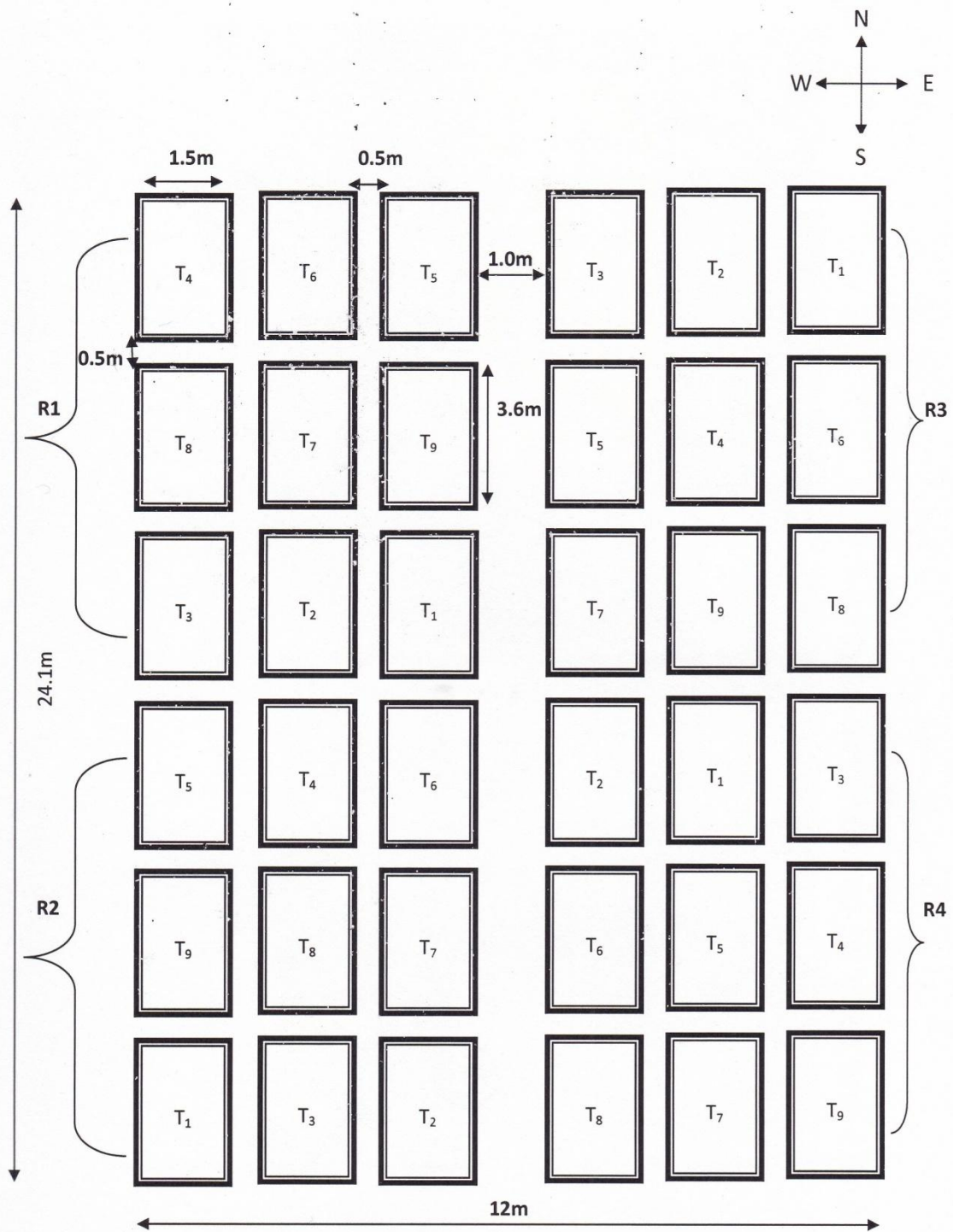


Fig. 3.2 Layout of the field experiment



Plate 1:- A Panoramic view of the experimental plot

3.6 Cultural practices

3.6.1 Preparation of the experimental plot

The experimental plot was ploughed twice by tractor drawn cultivator and leveled. The clods were crushed, weeds were removed and soil brought to fine tilth. The land was divided into plots of required size (3.6 m x 1.5 m). Provision was made for bunds and irrigation channels.

3.6.2 Application of manure and fertilizer

A basal dose of well rotted Farmyard manure at the rate of 10 tones per hectare was incorporated in the soil before one month of sowing. The calculated quantities of N, P, and K were applied to the respective plot. The source of nitrogen, phosphorus and potash were urea (46% N₂), Single Super Phosphate (16% P₂O₅) and Murate of Potash (60% K₂O) respectively.

Nitrogen as per treatment was given to plot in three doses. The half amount of nitrogen with full doses of P₂O₅ and K₂O were applied as basal, at the time of sowing. Remaining dose of ½ nitrogen as per treatment was applied in two equal splits at 45 days and 75 days after sowing with irrigation through urea.

3.6.3 Seed and sowing

The pure, healthy, disease and insect free and good quality nigella seed (NRCSS AN-1) was used for sowing. The seeds were sown at a depth of 2.5 cm in row spacing as per treatment. The sowing was done on 26 October 2015.

3.6.4 Thinning of seedlings

Thinning was done at 30 DAS to remove the excess plants to maintain uniform plant spacing of 10 cm.

3.6.5 Weeding

First weeding was done at 30 DAS and the 2nd and 3rd weeding at 45 and 75 DAS respectively, to keep the crop weed free.

3.6.6 Plant protection measure

The crop was sprayed with imidacloprid 17.8 SL at vegetative and capsule formation stage to prevent the aphid infestation. Soil was drenched with carbendazim @ 0.1%, twice at an interval of 65 and 90 DAS to prevent the root rot infection.

3.6.7 Irrigation

For the establishment of the crop, first light irrigation was done just after sowing, then subsequent irrigation were done at different interval, as per crop requirement.

Irrigation	Date
1 st	15/11/ 015
2 nd	10/12/ 015
3 rd	08/01/016
4 th	27/01/016
5 th	20/02/016

3.6.8 Harvesting

The crop was harvested on 14th march 2016. The nigella plant were harvested separately for each treatment.

3.6.9 Threshing and winnowing

After sun drying, the threshing of the individual plot was done with the help of wooden sticks and winnowed traditionally to separate seed and straw. Seed were weighed and plot wise samples were taken. Seed and straw were separated for further analysis.

3.6.10 Sampling technique

Five plants were randomly selected from each plot and tagged for recording observations on various characters.

3.6.11 Observations and procedure

Observations were recorded on the different parameters viz., growth, yield and quality attributing characters of nigella as detailed below.

3.6.12 Observations recorded during course of investigation

Growth attributes

1. Plant height (cm) at 45, 90 days and at harvest
2. Number of branches per plant at 45, 90 days and at harvest
3. Fresh weight of plant (g) at 45, 90 days and at harvest
4. Dry weight of plant (g) at 45, 90 days and at harvest

Yield attributes

1. Number of capsules per plant
2. Number of seeds per capsule
3. Test weight (g)
4. Seed yield (q/ha)
5. Biological yield (q/ha)
6. Straw yield (q/ha)
7. Harvest index (%)

Quality Parameter

1. Oil content in seed (%)
2. Protein content in seed (%)

3.6.13 Growth parameters

1. Plant height (cm)

Five plants were randomly selected from each plot for measuring plant height at 45, 90 DAS and at harvest. The plant height was measuring from the ground level to the tip of last leaf/flower. The average was worked out and expressed as plant height in cm.

2. Number of branches per plant

The branches from five randomly selected plants from each plot were counted at 45, 90 DAS and at harvest. The average was computed and expressed as number of branches/plant.

3. Fresh weight of plant (g)

Plant randomly selected in one meter row length and removed from each experimental unit at 45, 90 DAS and at harvest. The sample were first weight and average was worked out and was expressed as gram/plant.

4. Dry weight of plant (g)

After taking fresh weight, samples were first dried in air and then in oven at 65⁰C temperature for 24 hours till constant weight. The dry matter was weighted and average worked out and was expressed as g/plant.

3.6.14 Yield parameters

1. Number of capsules per plant

The capsule of five randomly selected plants from each plot at the time of harvesting were counted and average number of capsules/plant was calculated.

2. Number of seeds per capsules

Number of seed in five randomly selected capsules harvested from observation plants was counted and average number of seeds/capsule calculated.

3. Test weight (g)

One thousand seeds were counted in samples taken from the finally winnowed and cleared produce of each plot. These seeds were weighed on electronic balance and the weight was recorded as test weight (g).

4. Seed yield (q/ha)

After threshing and winnowing clean seeds obtained from individual plot were weighed and the weight recorded in kg/plot. This was converted in q/ha.

$$\text{Seed yield (q ha}^{-1}\text{)} = \frac{\text{Seed yield (g) / plot (sq m)} \times 10000}{\text{Size of plot (sq m)} \times 1000 \times 100}$$

5. Biological yield

The harvested and sun dried crop of each plot was weighed and the weight recorded in kg per plot converted to q per ha.

$$\text{Biological yield (q ha}^{-1}\text{)} = \frac{\text{Biological yield (g) / plot (sq m)} \times 10000}{\text{Size of plot (sq m)} \times 1000 \times 100}$$

6. Straw yield

Straw yield was calculated by subtracting the seed yield from the biological yield (q/ha).

7. Harvest Index (HI)

The harvest index was obtained by the economic yield (seed yield) from total biological yield and expressed as percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.15 Quality parameter

1. Oil content in seed (%)

Essential oil content in nigella was determined by using essential oil distillation assembly as per (A.O.A.C., 1995).

2. Protein content in seed (%)

The proteins were estimated by the method of crude protein content of the seeds. The crude protein content was obtained by multiplying the nitrogen content of the seeds by 6.25 and expressed in percent.

Procedure for analysis of total nitrogen in dried samples is detailed hereunder

Reagents

1. Copper sulphate
2. Potassium sulphate
3. 40% and N/20 NaOH
4. N/20 H₂SO₄
5. Phenolphthalein indicator

Method

- (i) 1g of ground plant sample was taken in digestion tube and 10 ml of concentrated sulphuric acid (H₂SO₄) was added in each tube.
- (ii) Then potassium sulphate (K₂SO₄) and copper sulphate (CuSO₄) added in the ratio 5:2 (3g/ sample).
- (iii) The digestion tube was placed on the digestion block and the digestion system set to a temperature of 400 - 410⁰c.
- (iv) The digestion was continued till black or brown colour of the sample disappeared and clear solution formed. Afterwards the samples were allowed to cool at room temperature.
- (v) The digested sample tube was placed in the distillation unit and distillation done using 40% NaOH solution.
- (vi) 10 ml of 4% boric acid solution was taken in a conical flask containing methyl red and methyl green indicator and the condenser outlet dipped in the flask.
- (vii) After distillation, boric acid solution was titrated against 0.1 N HCl. Blank was also run and titration was carried out to the same end point as that of the sample.
- (viii) The nitrogen content in plant sample was calculated as follows.

$$\text{Nitrogen (\%)} = \frac{(\text{Sample reading} - \text{Blank reading}) \times \text{Normality of HCl} \times 14}{\text{Weight of sample (g)} \times 100} \times 100$$

Crude protein (%) = Nitrogen (%) × 6.25

3.7 Statistical analysis

The experimental data recorded were subjected to statistical analysis using analysis of variance technique suggested by Pansey and Sukhatme (1985). The critical difference for the treatments comparison were worked out, wherever the “F” test was found significant at 5% level of significance. To elucidate effects, summary tables along with S.Em ± and critical differences has been given in the result chapter and their analysis of variance in the appendices at the end.

3.7.1 Standard error of mean (S.Em ±)

It is the measure of the mean difference between sample estimate of mean (\bar{x}) and the population parameter (μ) i.e. it is the measure of controlled variation present in a sample and is denoted by S.Em.r

$$S.Em \pm = \sqrt{EMSS/r}$$

Where, EMSS = Error mean sum of squares

r = Number of replications

3.7.2 Critical difference (CD)

Critical difference is used to compare the observed differences among different treatments. If the difference is greater than critical difference, it is considered as significant and vice versa.

$$CD = S Ed. \times t_{(%)}$$

Where, S Ed. = Standard error of difference

t = table value for error degrees of freedom.

Chapter- IV

RESULTS

Results of the field experiment conducted at College of Horticulture, Mandsaur in rabi, 2015-2016, entitled "Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)" are presented here and described in this Chapter. Results for all main effect are presented in this Chapter.

4.1 Effect of row spacing and nitrogen levels on growth parameters of nigella

4.1.1 Effect of row spacing and nitrogen levels on plant height :

Data pertaining to plant height at 45, 90 DAS and at harvest are presented in (Table 5 and Fig. 3). Plant height of nigella recorded at 45, 90 DAS and at harvest were significantly affected by different row spacing. Sowing of nigella at 30 cm row spacing recorded 20.81, 73.71 and 80.61 cm plant height at 45, 90 DAS and at harvest respectively, which were 29.41, 14.40 and 11.06 percent higher as compared to 15 cm row spacing.

The data further indicated that the nitrogen levels had significant effect on plant height at 45, 90 DAS and at harvest. Application of 60 kg nitrogen ha⁻¹ recorded significantly highest plant height of 20.10, 73.03 and 79.11 cm at 45, 90 DAS and at harvest as compared to lower levels of nitrogen.

Table 5: Effect of row spacing and nitrogen levels on plant height at different stages of crop growth of nigella.

Treatments	Plant height (cm)		
	45 DAS	90 DAS	At harvest
Row spacing (cm)			
15 (S ₁)	16.08	64.43	72.58
22.5 (S ₂)	18.50	67.31	75.21
30 (S ₃)	20.81	73.71	80.61
S.Em ±	0.52	1.63	1.17
CD at 5%	1.80	5.64	4.06
Nitrogen levels (kg ha⁻¹)			
20 (N ₁)	17.31	64.20	73.21
40 (N ₂)	17.98	68.23	75.41
60 (N ₃)	20.10	73.03	79.11
S.Em ±	0.44	1.69	1.02
CD at 5%	1.32	5.03	3.05

4.1.2 Effect of row spacing and nitrogen levels on number of branches per plant at different stages of crop growth of nigella.

It is explicit from the data (Table 6 and Fig. 4) that there was significant difference in number of branches per plant recorded at 45, 90 DAS and at harvest due to sowing of nigella at different spacing.

Sowing of nigella at 30 cm row spacing gave significant highest branches of 8.13, 8.43 and 9 at 45, 90 DAS and at harvest.

The data further indicated that the nitrogen levels had significant effect on number of branches per plant.

Application of 60 kg nitrogen ha⁻¹ gave significant maximum branches per plant at 45 DAS (8.05), 90 DAS (8.33) and at harvest (8.88) as compared to 20 kg nitrogen ha⁻¹.

Fig 3 Effect of row spacing and nitrogen levels on plant height at different stages of crop growth of nigella

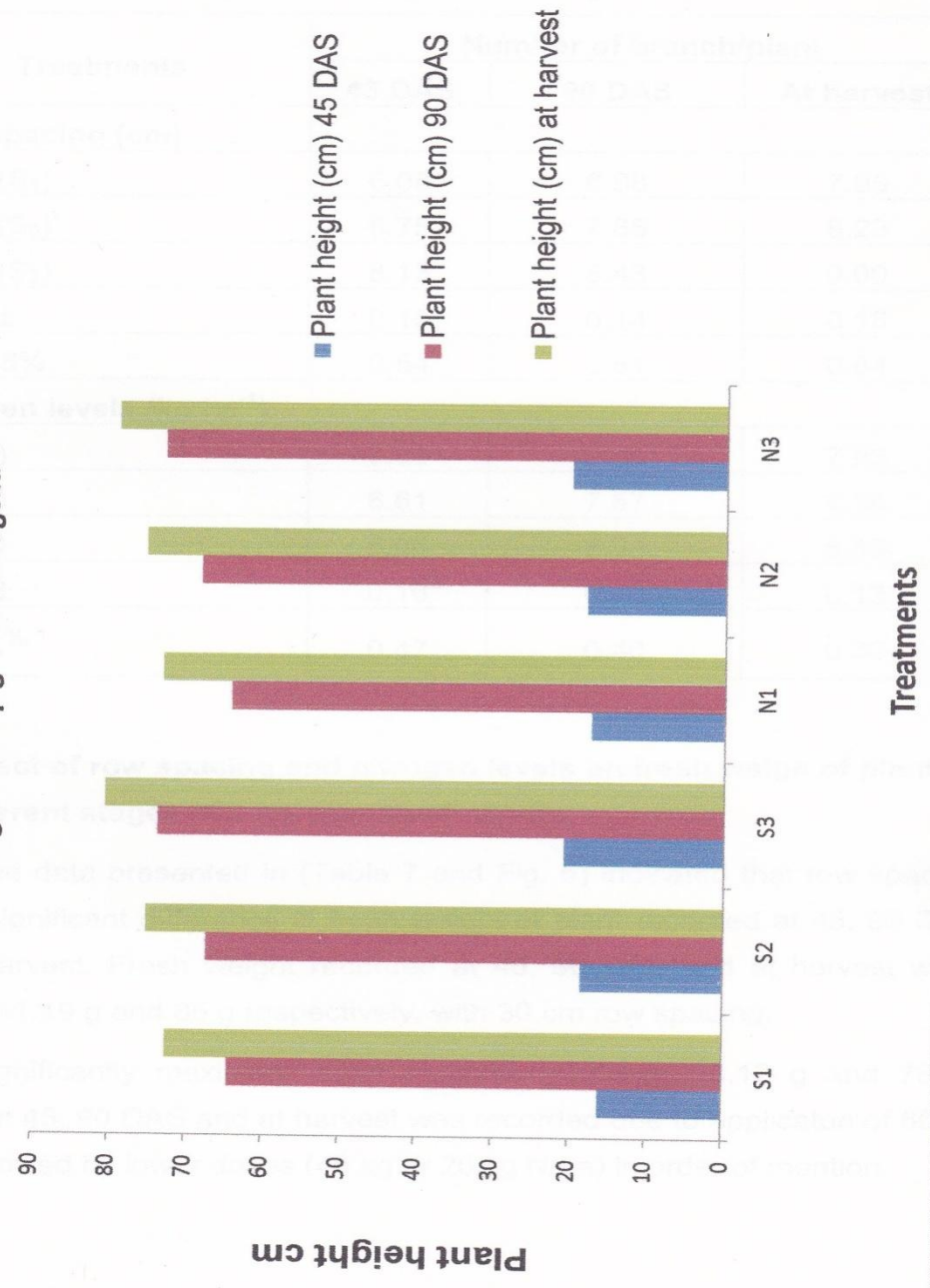


Table 6: Effect of row spacing and nitrogen levels on number of branch at different stages of crop growth of nigella.

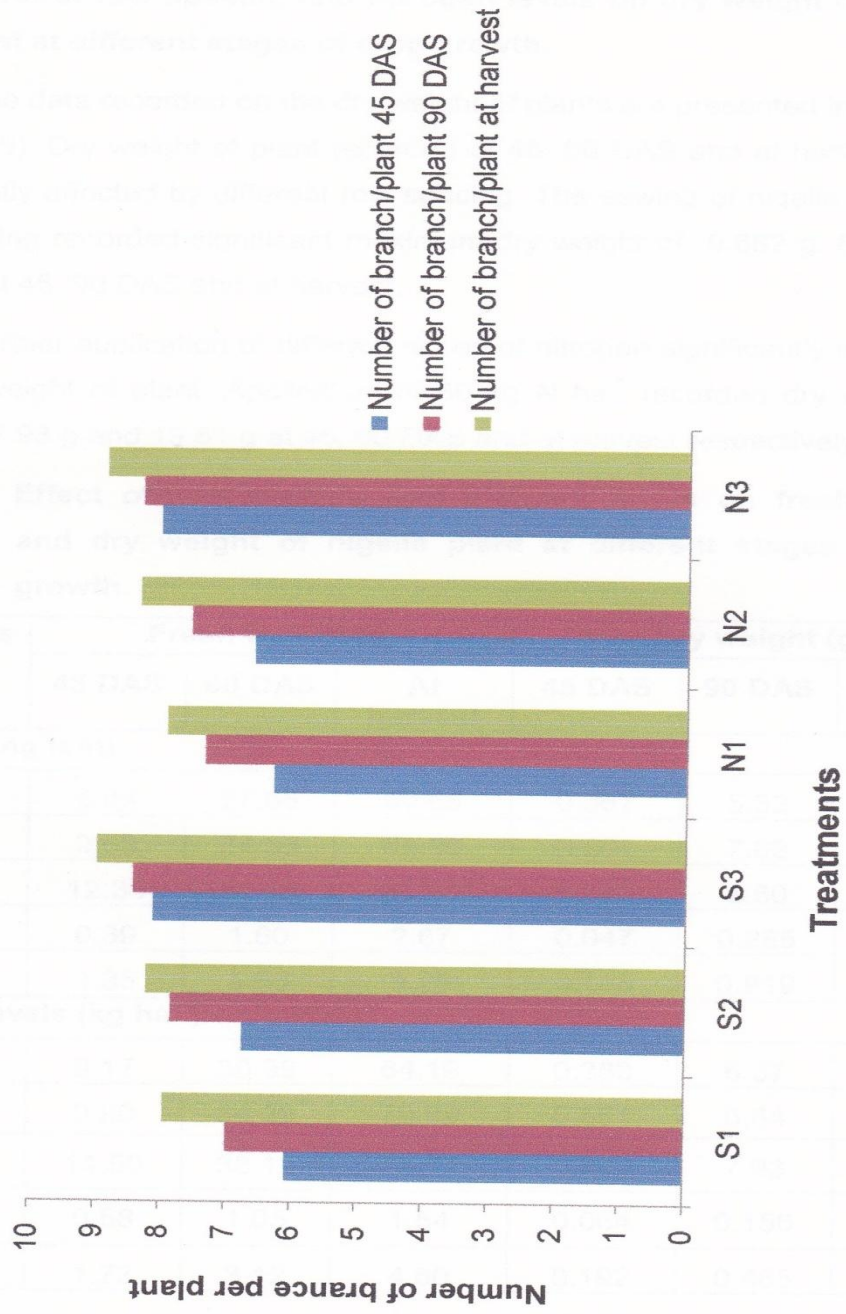
Treatments	Number of branch/plant		
	45 DAS	90 DAS	At harvest
Row spacing (cm)			
15 (S ₁)	6.08	6.98	7.95
22.5 (S ₂)	6.75	7.85	8.23
30 (S ₃)	8.13	8.43	9.00
S.Em ±	0.15	0.14	0.18
CD at 5%	0.54	0.51	0.64
Nitrogen levels (kg ha⁻¹)			
20 (N ₁)	6.30	7.35	7.93
40 (N ₂)	6.61	7.57	8.36
60 (N ₃)	8.05	8.33	8.88
S.Em ±	0.16	0.13	0.13
D at 5%	0.47	0.40	0.39

4.1.3 Effect of row spacing and nitrogen levels on fresh weigh of plant at different stages of crop growth of nigella.

The data presented in (Table 7 and Fig. 5) indicated that row spacing caused significant difference in fresh weight of plant recorded at 45, 90 DAS and at harvest. Fresh weight recorded at 45, 90 DAS and at harvest were 12.35 g, 41.19 g and 85 g respectively, with 30 cm row spacing.

Significantly maximum fresh of plant (11.50 g, 38.12 g and 78.77 g/plant) at 45, 90 DAS and at harvest was recorded due to applicaton of 60 kg N/ ha followed by lower doses (40 kg or 20 kg N/ha) in order of mention.

Fig 4 Effect of row spacing and nitrogen levels on number of branch at different stages of crop growth of nigella



4.1.4 Effect of row spacing and nitrogen levels on dry weight of nigella plant at different stages of crop growth.

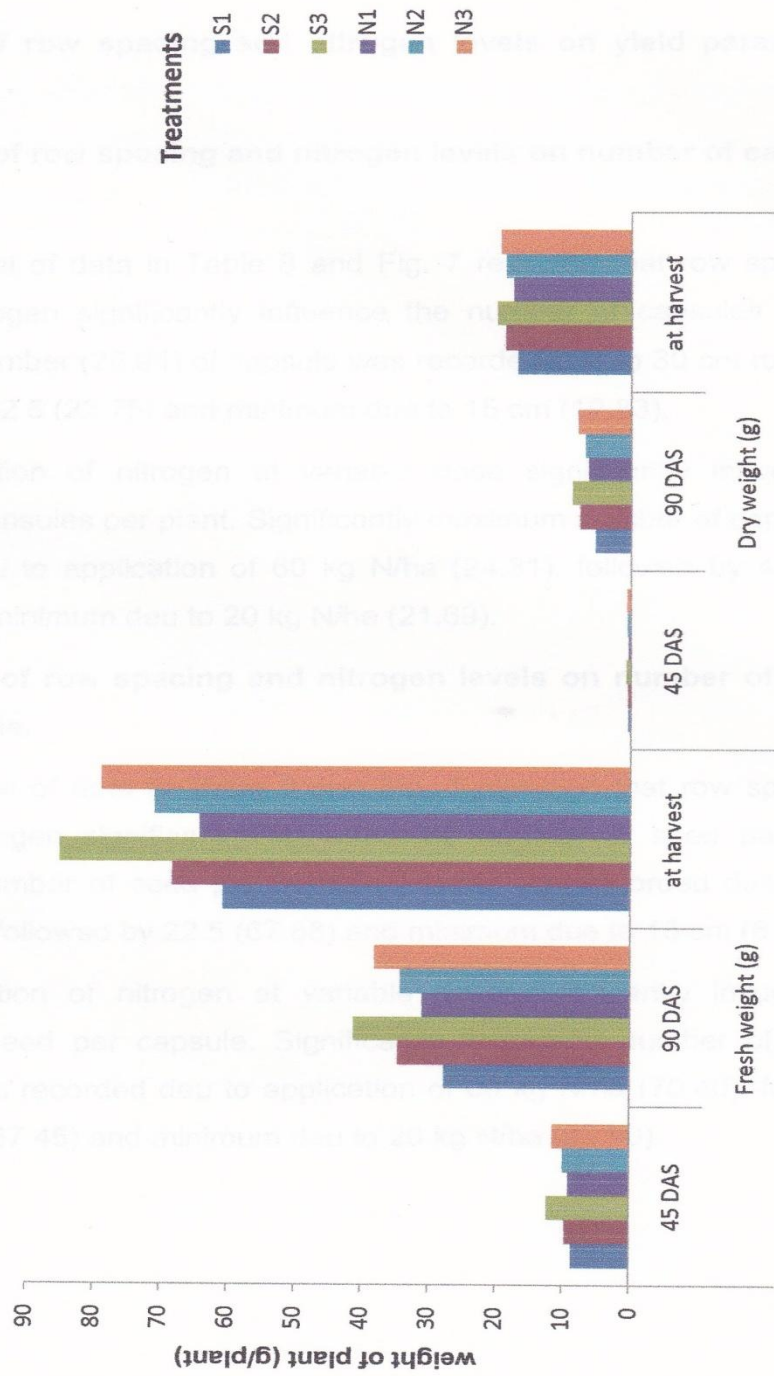
The data recorded on the dry weight of plants are presented in (Table 7 and Fig. 6). Dry weight of plant recorded at 45, 90 DAS and at harvest were significantly affected by different row spacing. The sowing of nigella at 30 cm row spacing recorded significant maximum dry weight of 0.682 g, 8.8 g and 20.06 g at 45, 90 DAS and at harvest.

Further application of different doses of nitrogen significantly increased the dry weight of plant. Application of 60 kg N ha⁻¹ recorded dry weight of 0.620 g, 7.93 g and 19.51 g at 45, 90 DAS and at harvest respectively.

Table 7: Effect of row spacing and nitrogen levels on fresh weight and dry weight of nigella plant at different stages of crop growth.

Treatments	Fresh weight (g)			Dry weight (g)		
	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest
Row spacing (cm)						
15 (S ₁)	8.64	27.65	60.65	0.367	5.32	16.92
22.5 (S ₂)	9.59	34.55	68.20	0.501	7.62	18.78
30 (S ₃)	12.35	41.19	85.00	0.682	8.80	20.06
S.Em ±	0.39	1.60	2.67	0.047	0.265	0.371
CD at 5%	1.35	5.56	9.25	0.165	0.919	1.284
Nitrogen levels (kg ha⁻¹)						
20 (N ₁)	9.17	30.99	64.19	0.380	6.37	17.59
40 (N ₂)	9.90	34.29	70.89	0.551	6.84	18.65
60 (N ₃)	11.50	38.12	78.77	0.620	7.93	19.51
S.Em ±	0.58	1.05	1.54	0.064	0.156	0.232
CD at 5%	1.73	3.12	4.60	0.192	0.465	0.691

Fig- 5 Effect of row spacing and nitrogen levels on fresh weight and dry weight plant at different stages of nigella.



4.2 Effect of row spacing and nitrogen levels on yield parameters of nigella.

4.2.1 Effect of row spacing and nitrogen levels on number of capsule per plant.

Perusal of data in Table 8 and Fig. 7 revealed that row spacing and dose of nitrogen significantly influence the number of capsules per plant. Maximum number (25.94) of capsule was recorded due to 30 cm row spacing followed by 22.5 (22.75) and minimum due to 15 cm (19.83).

Application of nitrogen at variable dose significantly influenced the number of capsules per plant. Significantly maximum number of capsules was recorded due to application of 60 kg N/ha (24.31), followed by 40 kg N/ha (22.52) and minimum due to 20 kg N/ha (21.69).

4.2.2 Effect of row spacing and nitrogen levels on number of seed per capsule.

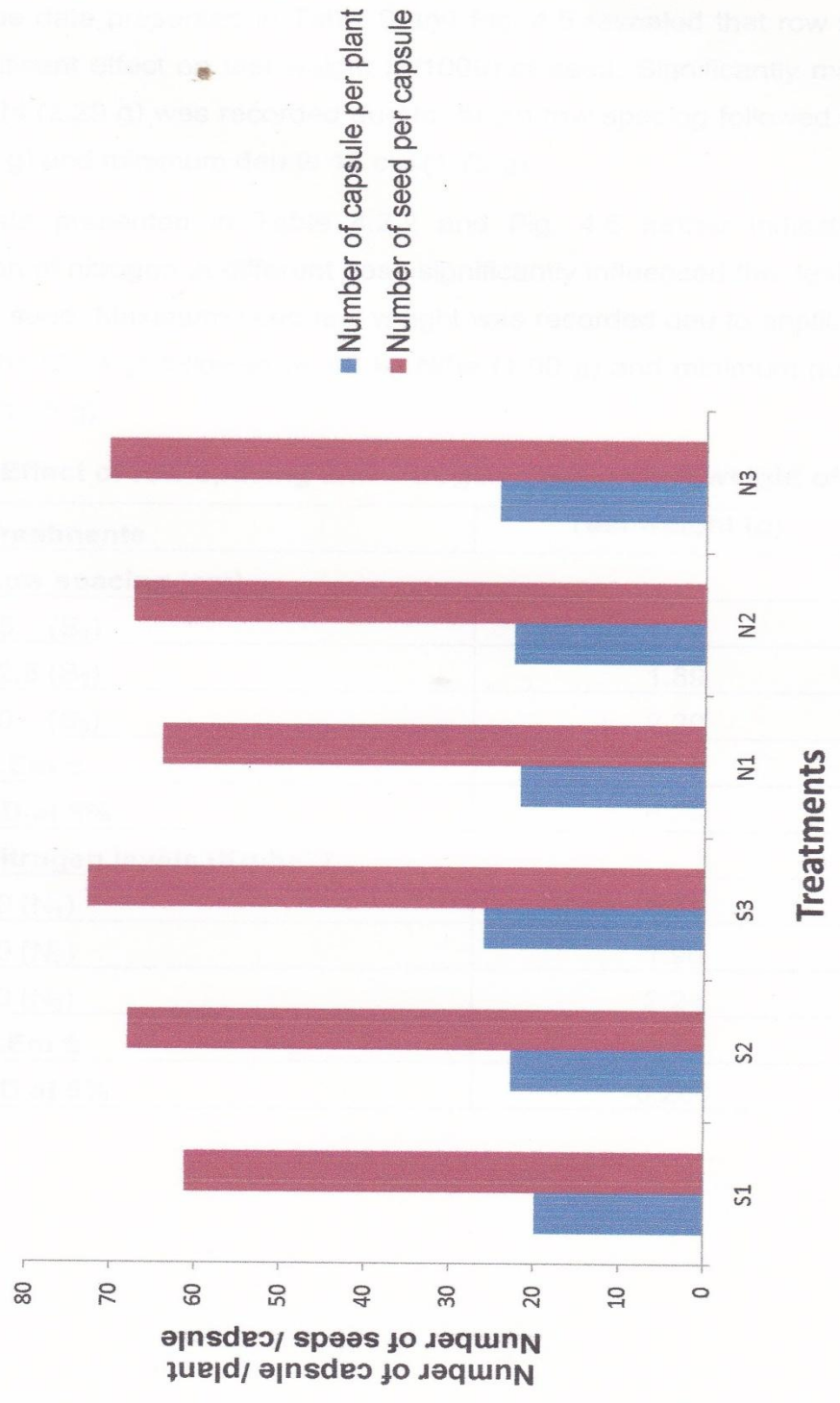
Perusal of data in Table 8 and Fig. 7 revealed that row spacing and dose of nitrogen significantly influence the number of seed per capsule. Maximum number of seed per capsule (72.71) was recorded due to 30 cm row spacing followed by 22.5 (67.88) and minimum due to 15 cm (61.15).

Application of nitrogen at variable dose significantly influenced the number of seed per capsule. Significantly maximum number of seed per capsules was recorded due to application of 60 kg N/ha (70.40), followed by 40 kg N/ha (67.45) and minimum due to 20 kg N/ha (63.90).

Table 8: Effect of row spacing and nitrogen levels on number of capsule per plant and number of seed per capsule.

Treatments	Number of capsule per plant	Number of seed per capsule
Row spacing (cm)		
15 (S ₁)	19.83	61.15
22.5 (S ₂)	22.75	67.88
30 (S ₃)	25.94	72.71
S.Em ±	0.74	1.04
CD at 5%	2.56	3.60
Nitrogen levels (Kg ha⁻¹)		
20 (N ₁)	21.69	63.90
40 (N ₂)	22.52	67.45
60 (N ₃)	24.31	70.40
S.Em ±	0.42	0.82
CD at 5%	1.25	2.45

Fig. 6 Effect of row spacing and nitrogen levels on number of capsule per plant and number of seed per capsule



4.2.3 Effect of row spacing and nitrogen levels on test weight (g).

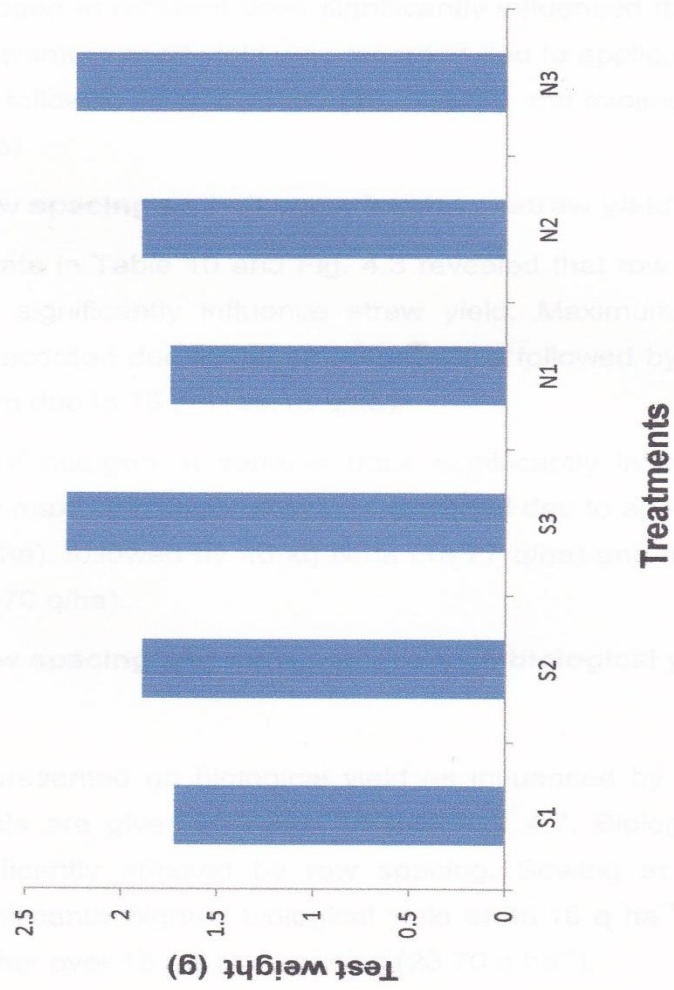
The data presented in Table 9 and Fig. 4.5 revealed that row spacing had significant effect on test weight (g/1000) of seed. Significantly maximum test weight (2.29 g) was recorded due to 30 cm row spacing followed by 22.5 cm (1.89 g) and minimum due to 15 cm (1.72 g).

Data presented in Table 4.2.2 and Fig. 4.5 further indicated that application of nitrogen at different dose significantly influenced the test weight of nigella seed. Maximum seed test weight was recorded due to application of 60 kg N/ha (2.24 g) followed by 40 kg N/ha (1.90 g) and minimum due to 20 kg N/ha (1.75 g).

Table 9: Effect of row spacing and nitrogen dose on test weight of seed

Treatments	Test weight (g)
Row spacing (cm)	
15 (S ₁)	1.72
22.5 (S ₂)	1.89
30 (S ₃)	2.29
S.Em ±	0.07
CD at 5%	0.24
Nitrogen levels (Kg ha⁻¹)	
20 (N ₁)	1.75
40 (N ₂)	1.90
60 (N ₃)	2.24
S.Em ±	0.08
CD at 5%	0.260

Fig.7 - Effect of row spacing and nitrogen levels on test weight of seed



4.2.4 Effect of row spacing and nitrogen levels on seed yield ($q\ ha^{-1}$).

The data presented in Table 10 and Fig. 8 revealed that row spacing had significant effect on seed yield q/ha . Significantly maximum seed yield (12.18 q/ha) was recorded due to 30 cm row spacing followed by 22.5 cm (9.95 q/ha) and minimum due to 15 cm (8.57 q/ha).

Data presented in Table 10 and Fig. 4.5 further indicated that application of nitrogen at different dose significantly influenced the seed yield of nigella seed. Maximum seed yield was recorded due to application of 60 kg N/ha (11.72 q/ha) followed by 40 kg N/ha (10.22 q/ha) and minimum due to 20 kg N/ha (8.76 q/ha).

4.2.5 Effect of row spacing and nitrogen levels on straw yield ($q\ ha^{-1}$).

Perusal of data in Table 10 and Fig. 4.3 revealed that row spacing and dose of nitrogen significantly influence straw yield. Maximum straw yield (22.98 q/ha) was recorded due to 30 cm row spacing followed by 22.5 (17.22 q/ha) and minimum due to 15 cm (15.13 q/ha).

Application of nitrogen at variable dose significantly influenced straw yield. Significantly maximum straw yield was recorded due to application of 60 kg N/ha (20.87 q/ha). followed by 40 kg N/ha (18.77 q/ha) and minimum due to 20 kg N/ha (15.70 q/ha).

4.2.6 Effect of row spacing and nitrogen levels on biological yield ($q\ ha^{-1}$).

The data presented on biological yield as influenced by row spacing and nitrogen levels are given in Table 10 and Fig. 4.7. Biological yield of nigella was significantly affected by row spacing. Sowing at 30 cm row spacing gave significantly highest biological yield of 35.16 $q\ ha^{-1}$. Which was 48.35 percent higher over 15 cm row spacing (23.70 $q\ ha^{-1}$).

Further data (Table 10 and Fig. 4.7) reveals that application of nitrogen having significant effect on biological yield. Application of 60 kg N ha^{-1} recorded significantly highest biological yield (32.59 $q\ ha^{-1}$). The increment in

biological yield under the influence of 60 kg N ha⁻¹ was 33.18 percent over 20 kg N ha⁻¹.

4.2.7 Effect of row spacing and nitrogen levels on harvest index (%).

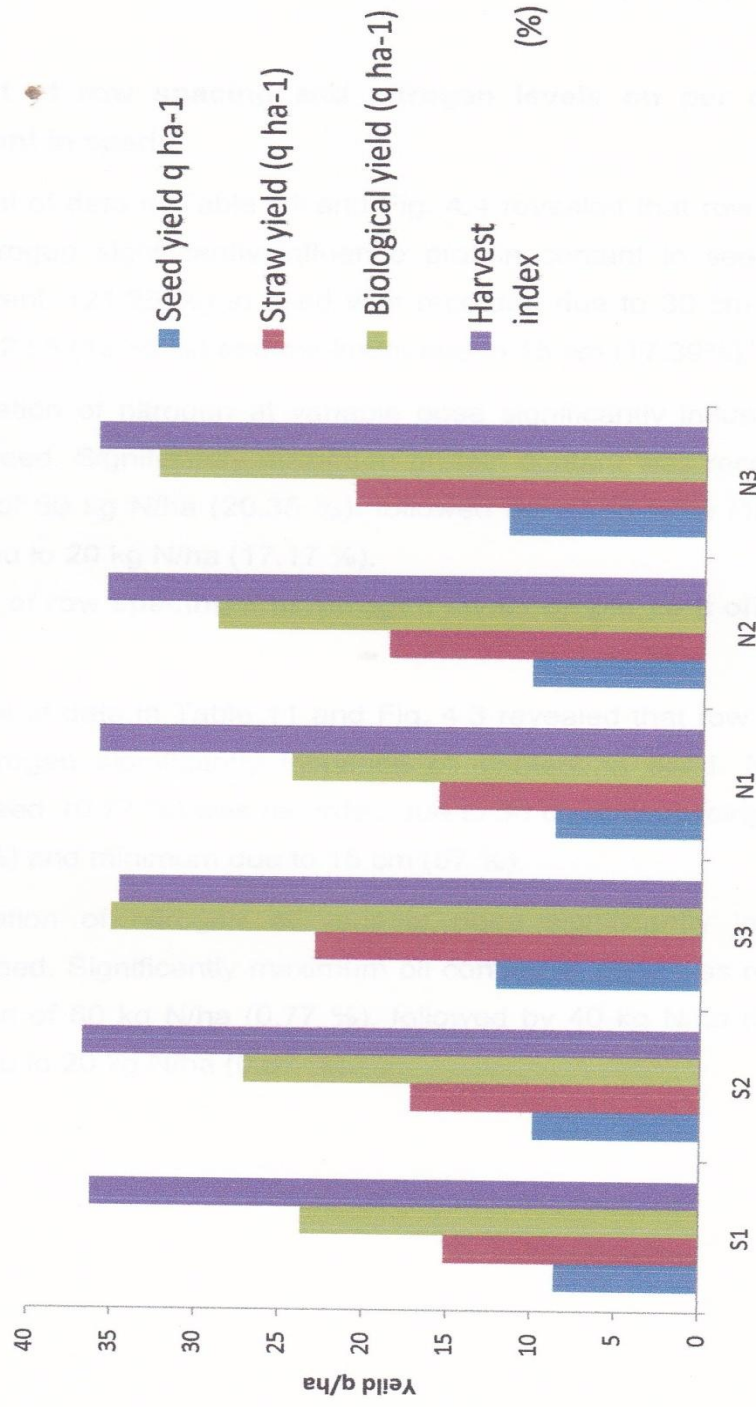
A perusal of data in Table 10 and Fig. 4.8 reveals that different row spacing did not bring any significant variation on harvest index.

It is evident from the data (Table 4.2.7 and Fig. 4.8) that application of nitrogen did not found significant effect on harvest index.

Table 10: Effect of row spacing and nitrogen levels on seed yield, straw yield, biological yield and harvest index.

Treatments	Seed yield q ha ⁻¹	Straw yield (q ha ⁻¹)	Biological yield (q ha ⁻¹)	Harvest index (%)
Row spacing (cm)				
15 (S ₁)	8.57	15.13	23.70	36.25
22.5 (S ₂)	9.95	17.22	27.18	36.78
30 (S ₃)	12.18	22.98	35.16	34.69
S.Em ±	0.38	0.944	1.303	0.616
CD at 5%	1.34	3.268	4.511	NS
Nitrogen levels (Kg ha⁻¹)				
20 (N ₁)	8.76	15.70	24.47	35.97
40 (N ₂)	10.22	18.77	28.99	35.60
60 (N ₃)	11.72	20.87	32.59	36.15
S.Em ±	0.48	0.891	1.304	0.858
CD at 5%	1.442	2.650	3.874	NS

Fig 8 Effect of row spacing and nitrogen levels seed yield, straw yield, biological yield and harvest index



4.3 Effect of row spacing and nitrogen levels on quality parameters of nigella.

4.3.1 Effect of row spacing and nitrogen levels on per cent protein content in seed.

Perusal of data in Table 11 and Fig. 4.4 revealed that row spacing and dose of nitrogen significantly influence protein content in seed. Maximum protein content (21.25 %) in seed was recorded due to 30 cm row spacing followed by 22.5 (18.65 %) and minimum due to 15 cm (17.39%).

Application of nitrogen at variable dose significantly influenced protein content in seed. Significantly maximum protein content was recorded due to application of 60 kg N/ha (20.35 %), followed by 40 kg N/ha (19.17 %) and minimum due to 20 kg N/ha (17.17 %).

4.3.2 Effect of row spacing and nitrogen levels on per cent oil content in seed.

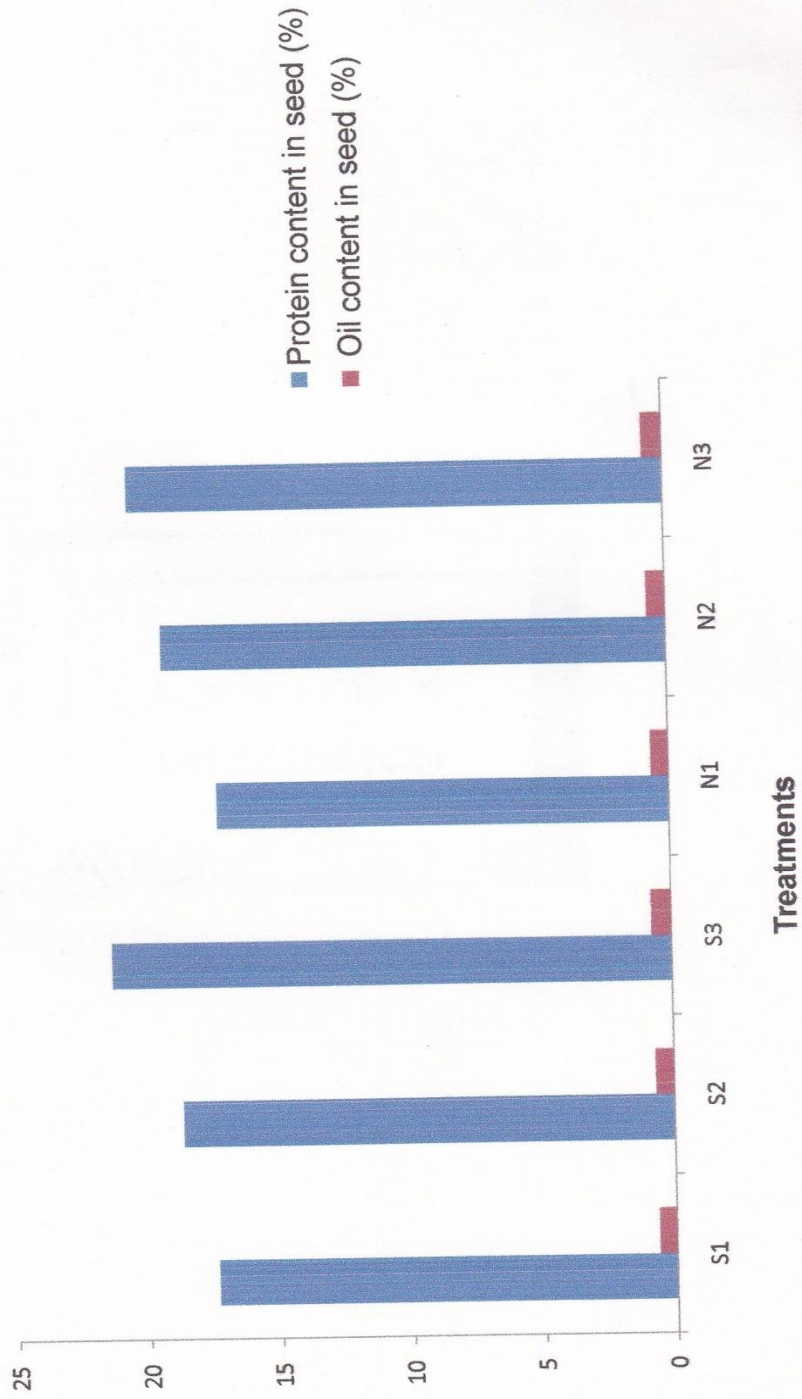
Perusal of data in Table 11 and Fig. 4.3 revealed that row spacing and dose of nitrogen significantly influence oil content in seed. Maximum oil content in seed (0.77 %) was recorded due to 30 cm row spacing followed by 22.5 (0.71 %) and minimum due to 15 cm (0.67 %).

Application of nitrogen at variable dose significantly influenced oil content in seed. Significantly maximum oil content in seed was recorded due to application of 60 kg N/ha (0.77 %), followed by 40 kg N/ha (0.71 %) and minimum due to 20 kg N/ha (0.67 %).

Table 11: Effect of row spacing and nitrogen levels on protein content in seed (%) and oil content in seed (%).

Treatments	Protein content in seed (%)	Oil content in seed (%)
Row spacing (cm)		
15.0 (S ₁)	17.39	0.67
22.5 (S ₂)	18.65	0.71
30.0 (S ₃)	21.25	0.77
S.Em ±	0.22	0.01
CD at 5%	0.78	0.05
Nitrogen levels (Kg ha⁻¹)		
20 (N ₁)	17.17	0.67
40 (N ₂)	19.17	0.71
60 (N ₃)	20.35	0.77
S.Em ±	0.26	0.01
CD at 5%	0.78	0.05

Fig-9 Effect of row spacing and nitrogen levels on protein content in seed (%) and oil content in seed (%)



Chapter-v

DISCUSSION

In the course of presenting the results (chapter IV) of experiment entitled “**Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)**” significant variation in the criteria used for evaluating the treatments have been described. In the present chapter, it is endeavored to discuss the results in the light of available in literature.

5.1 Effect of row spacing

5.1.1 Growth attributes

The results indicated that crop at wider row spacing 30 cm recorded highest plant height, number of branches, fresh and dry weight of plant. Significant improvement in aforesaid parameters due to increase in spacing or in other words reduction in plant population per unit area could be ascribed to availability of more area per plant which implied that individual plant at wider spacing received higher growth inputs (sunlight, water and nutrients) with least competition as compared to the plants grown under other two closer row spacing. Thus greater inputs under wider spacing (S_3) resulted in profuse branching which in turn might have helped in larger canopy development.

The larger canopy development associated with profuse branching has increased interception, absorption and utilization of solar energy resulting in formation of higher photosynthates and finally dry matter per plant. Significant improvement in growth with increase in spacing is in close conformity with the findings of Meena *et al.* (2011) and Meena *et al.* (2012) in nigella crop, Naruka *et al.* (2012) in ajowan and Meena *et al.* (2015) in dill.

5.1.2 Yield attributes

It was observed that successive increase in row spacing from 15 cm to 30 cm significantly improved various yield attributes of nigella. Number of capsules per plant, number of seed per capsules, test weight, seed yield, biological and straw yield (Table 8, 9 and 10) were improved due to each

increase in spacing and the maximum value for these estimates were obtained at the 30 cm row spacing (S_3), while least under closer spacing (S_1). However, results with respect to productivity revealed that crop grown under wider row spacing (S_3) produced more number of capsules per plant (25.94), number of seed per capsule (72.71), test weight (2.29 g), seed yield (12.18 q ha^{-1}), straw yield (22.98 q ha^{-1}) and total biological yield (35.16 q ha^{-1}) compared to other row spacing (S_1 and S_2).

Marked improvement in yield attributes of the crop with increase in spacing appear to be on account of vigorous growth of the plants as is evident from profuse branching and higher biomass accumulation per plant. The profuse branching seems to have led to enhanced of flowering and adequate supply of metabolites due to the increase in biomass per plant might have helped in retention of flower there by greater seed formation and seed growth. This was ultimately reflected in increased seed yield per plant.

The observed crop performance with respect to yield potential under the influence of spacing could be mainly ascribed to primary function of number of plant per hectare and secondarily growth and development of the crop. These finding are also supported by Meena *et al.* (2011), Meena *et al.* (2012), and Malhotra and Vashishtha (2008) in nigella and Meena *et al.* (2013) in dill.

5.1.3 Quality attributes

It was observed that each increase in row spacing from S_1 to S_3 significantly improved protein and oil content in seed (Table 11).

Significantly more protein and oil content in seed under row spacing (S_3) could be ascribed to availability of more space per plant resulting in profuse vegetative growth. These finding are also supported by Malhotra and Vashishtha (2008), Meena *et al.* (2011) and Meena *et al.* (2012) in nigella.

5.2 Effect of nitrogen levels

5.2.1 Growth attributes

Data presented in table 5, 6 and 7 revealed that the application of nitrogen fertilizer levels exerted significant influence on growth parameter. Maximum plant height (cm), number of branches, fresh weight and dry weight (g) were recorded under 60 kg N ha⁻¹ followed by 40 and 20 kg N ha⁻¹ at all the growth stages.

Higher levels of nitrogen fertilizer may be attributed to better nutritional environment in the root zone as well as in the plant system. It is amply established that nitrogen is the most indispensable of all mineral nutrient for growth and development of the plant as it is the basis of fundamental constituents of all living matter. It plays a vital role in plant metabolism by virtue of being an essential constituent of diverse type of metabolically active compounds, like amino acid, protein, nucleic acid, porphyrins, flavins, purine and pyrimidine nucleotides, flavin nucleotides, enzymes, co-enzyme and alkaloids. The biological role of nitrogen as an essential constituent of chlorophyll in harvesting solar energy, phosphorylated compound in energy transformation, nucleic acid in the transfer of genetic information and the regulation of cellular metabolism and of protein as structural unit and biological catalysts is well known.

5.2.2 Yield attributes

The data in table 8, 9 and 10 revealed that maximum number of capsules per plant, number of seed per capsule, test weight, seed yield, biological yield and straw yield of nigella increased significantly with application of 60 kg N ha⁻¹. This increase in yield attributes was significant for 60 kg N ha⁻¹ as compared to other dose of nitrogen.

Increased yield may be due to the role of fertilizer in improving uptake of nutrient by root system, increased chlorophyll content, photosynthesis activity and protein content in crop plant. These finding are also supported by Natraraja *et al.* (2003), Malhotra and Vashishtha (2008), Goswami (2011) and Rana *et al.* (2012) in nigella.

5.2.3 Quality attributes

A perusal of data (Table 11) indicated that nitrogen @ 60 kg/ha was significantly superior to other lower dose (40 or 20 kg/ha) with respect to quality attributes viz. protein and oil content in seed. There was significant increase in protein and oil content in seed with increasing levels of nitrogen. Maximum value of protein and oil content in seed were found due to application of 60 kg N ha⁻¹ application, followed by 40 and 20 kg N ha⁻¹. Similar findings were also reported by Malhotra and Vashishtha (2008) and Rana *et al.* (2012) in nigella.

Chapter-VI

SUMMARY, CONCLUSION AND SUGGESTIONS

The results of the field experiment “**Effect of row spacing and nitrogen levels on growth, yield and quality of nigella (*Nigella sativa* L.)**” conducted during 2015 – 2016 as presented and discussed in the preceding sections are being summarized hereunder.

6.1 Summary

6.1.1 Row spacing

Wider row spacing S_3 (30 cm) significantly increased the growth attributes viz., plant height, number of branches per plant, fresh weight and dry weight of plant at 45, 90 DAS and at harvest compared to closer row spacing.

Row spacing S_3 (30 cm) significantly increased the yield and yield attributes viz., number of capsules per plant, number of seed per capsules, test weight, seed yield $q\ ha^{-1}$, straw yield $q\ ha^{-1}$ and biological yield $q\ ha^{-1}$, in comparison to other row spacing.

Row spacing S_3 significantly increased the quality attributes like protein and oil content in seed in comparison to other row spacing.

6.1.2 Nitrogen levels

Among various Nitrogen levels tried, $60\ kg\ N\ ha^{-1}$ exhibited significantly maximum plant height, number of branches per plant, fresh weight and dry weight per plant at 45, 90 DAS and at harvest.

Similarly, Nitrogen level N_3 ($60\ kg\ N\ ha^{-1}$) significantly increased yield attributes viz. number of capsules per plant, number of seed per capsules, test weight (g), seed yield $q\ ha^{-1}$, straw yield $q\ ha^{-1}$ and total biological yield $q\ ha^{-1}$ in comparison to other nitrogen levels viz. N_2 ($40\ kg\ N\ ha^{-1}$) or N_1 ($20\ kg\ N\ ha^{-1}$).

Quality attributes viz., protein and oil content of seed were significantly enhanced with the nitrogen levels N_3 (60 kg N ha^{-1}) in comparison to other Nitrogen levels viz. N_2 (40 kg N ha^{-1}) or N_1 (20 kg N ha^{-1}).

6.2 Conclusion

On the basis of one year research it could be concluded that the row spacing and nitrogen levels significantly influenced the growth, yield and quality of nigella. The growth, yield and quality of nigella crop can be increased by sowing of nigella seed at the row spacing of $30 \times 10 \text{ cm}$ (S_3) with the application of 60 kg N ha^{-1} (N_3).

6.3 Suggestions

The following suggestions are made for further research work.

1. The experiment may be repeated to confirm the findings of the present experiment.
2. In the repeated experiment other plant geometry should be tested.
3. Similarly, the nitrogen levels with other major and minor nutrient levels should be tested.
4. A complete check (without fertilizer application) may be maintained to draw regression model for yield optimization of nigella.
5. The prospects of organic cultivation can also tried.

Chapter-VII

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VITA

Name of author : **Rahul Kumar Goutam**
Father's name : Mr. Atmaram Goutam
Date of Birth : 5th may 1990
Place of Birth : Balaghat (M.P.)
Address : Naharu nager professor colony Durg (C.G.) 490020

Academic qualification:

CLASS	BOARD/ UNIVERSITY	SUBJECTS	YEAR	Percentage /OGPA
M.Sc.(Hort)	RVSKVV, Gwalior	Horticulture, PSMA	2016	73.23 % (7.32)
BS.c.(Hort)	IGKV, Raipur (C.G.)	Agriculture	2014	68.83% (6.88)
Higher Secondary (10+2)	M.P. BOARD, Bhopal	Agriculture	2010	67.80%
High School	M.P. BOARD, Bhopal	All subject	2007	50%

The author may be contacted at:


Rahul Kumar Goutam

Naharu nager professor colony

Durg (C.G.) 490020